INFLUENCE OF VEGETATION AND GEOLOGY ON THE NUTRIENT AND HEAVY METAL TRANSPORT CAPABILITIES OF SEDIMENT

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INFLUENCE OF VEGETATION AND GEOLOGY ON THE NUTRIENT AND HEAVY METAL TRANSPORT CAPABILITIES OF SEDIMENT

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ABSTRACT

Soil, stream bank, and stream sediment material was collected from three vegetation types (Ponderosa pine, mixed conifer, and spruce-fir) on four different parent bedrock types (sandstone, limestone, basalt, and granite) and were analyzed for the following chemical components: acid digestable Ca, Mg, Na, K, Fe, Mn, Cu, and Zn; total N and P, extractable Ca, Mg, and K; cation exchange capacity; and organic matter. Vegetation type and parent bedrock were found to be highly significant factors in an analysis of variance for nearly all the chemical components. Differences were found between soil, stream bank, and stream sediment for some chemical components representing changes which occur with transport of the material within the watershed. Examples are given illustrating how the use of mean chemical values and sediment yield can estimate quantities of nutrients and heavy metals transported by suspended sediment.

INTRODUCTION

Studies of small watershed ecosystems have been valuable in assessing the effect of land management operations on nutrient loss (Likens et al., 1970). These studies are conducted on relatively small areas of known, often uniform, bedrock composition and a single vegetation type to be able to accurately evaluate a management procedure. Nurtient losses from such ecosystems result primarily from stream export. Dissolved ion concentrations are commonly measured, however, a potentially important source of nutrient and heavy metal loss, which is often ignored, is that transported by sediment (Gifford and Busby, 1973; Fisher and Minckley, 1978). Nutrients contained on or within suspended sediment can become available to aquatic organisms (Carignan and Kalff, 1979) and can influence the soluble concentrations in water (Aston and Thornton, 1977). Transported sediment has been shown to carry high levels of nutrients and heavy metals (Potter et al., 1975; Angino et al., 1974), however, most of these studies have looked at sediment derived from large drainages composed of many different bedrock and vegetation combinations. Virtually none have addressed the nutrient and heavy metal transport capacity of sediment from small, uniform watersheds in the western U.S.

We propose that sediment of a given size classification derived from small watersheds of uniform bedrock and a single vegetation type would have a uniform nutrient and heavy metal transport capacity. This capacity is a function of the weathering forces of the physical and biological environment (represented by the vegetation) acting upon the parent bedrock. In addition to the direct influence that the organisms of a certain vege-

tation type have on soil weathering rates (Graustein and Cromack, 1977; Jackson and Voigt, 1971), vegetation type also reflects a certain combination of temperature and moisture conditions which greatly influence bedrock weathering (Brady, 1974). The uniform nature of many small research watersheds is expected to yield sediment with a transport capacity which can be characterized with a relatively small sampling program.

Gosz et al. (1980) reported on a preliminary test of the hypothesis by comparing Ponderosa pine communities on 4 different bedrock. The analyses of the size fractions yielded significant differences between the communities and supported the hypothesis that bedrock was a significant factor in determining the transport capacity of sediment. This paper reports on the analyses of soil, stream bank, and stream sediment material collected from mixed conifer and spruce-fir communities on the same type of bedrock as the pine communities. These results would enable us to determine if vegetation type and the various interaction factors were significant in determining the transport capacity of the sediment.

METHODOLOGY

Three discrete samples of the following materials were taken from different locations within the watersheds: 0-15 cm soil depth in the forest, stream bank material which represents potentially transported material, and stream channel sediment which would be immediately available for stream transport. Gosz et al. (1980) found this sample size taken in this manner to yield standard errors less than or about equal to 10% of the mean values.

The samples were separated by sieving into three size fractions: greater than 2 mm used for visual mineral identification, "sand" (0.061 -

2.0 mm), and "fines (< 0.061 mm). The sand and fine fractions were analyzed for the following components: Acid digestable Ca, Mg, Na, K, Mn, Cu, and Zn following digestion with HNO_3 - HCl (Anderson, 1974); extractable cations and cation exchange capacity by ammonium saturation followed by acid-NaCl extraction (Gosz et al., 1980); and organic matter by loss on ignition at 500°C (St. John and Rundel, 1976). A detailed description of methods is available in Gosz et al. (1980).

SITE DESCRIPTIONS

The majority of the watersheds chosen are research areas which have been studied for some time. Many have sediment catchment basins which allowed the comparison of actual transported sediment to sediment which we collected in the stream channel prior to export from the watershed.

Ponderosa pine on granite (Site G-P, see Fig. 1)

The Tesuque Watersheds, located northeast of Santa Fe, New Mexico, are established on pre-Cambrian granitic gneiss composed of the following material (ranging from most to least abundant): K-feldspar, quartz, biotite, other micas, plagioclase, epidote, almandite, sillimanite, and other trace minerals. The valleys in the Ponderosa pine communities of the area support mixed-conifer species due to cold air drainage and the more mesic conditions than the rest of the watershed.

Ponderosa pine on basalt (Site B-P)

The Beaver Creek Watersheds are located south of Flagstaff, Arizona. The greater than 2 mm size fraction identified the parent material as amygdaloidal andesite with the following relative percent composition: Ca-plagioclase 60%, Na-plagioclase 20%, magnetite 15%, quartz 5%, and

trace minerals including K-feldspar, olivine, and biotite. The rocks were moderately to highly weathered.

Ponderosa pine on sandstone (Site S-P)

The Heber Watersheds, located northeast of Phoenix, Arizona, are established on parent material of orthoquartzite with varying amounts of magnetite, micas, and other components of granitic gneiss.

Ponderosa pine on limestone (Site L-P)

The Sacramento Forest east of Cloudcroft, New Mexico, is established on limestone of marine origin and is composed of primarily $CaCO_3$ with smaller amounts of $MgCO_3$ and 5-10% composition of chert. Most of the material was highly weathered and the fine material in the pores were high in organic material.

Mixed conifer on basalt (Site B-M)

Thomas Creek Watersheds, near Alpine, Arizona, are established on amygdaloidal basalt of the following relative composition (ranging from the most to least abundant): Ca-plagioclase, magnetite, hornblende, Na-plagioclase, quartz, and other trace minerals. Weathering was intense and the rocks were highly altered with substantial amounts of indistinquishable matrix material.

Mixed conifer on sandstone (Site S-M)

Located northwest of Las Vegas, New Mexico, this watershed borders the Pecos Wilderness near Hermit Peak. The sandstone is interbedded with layers of siltstone, shales, and some limestone and is composed of: quartz, feldspar, mica, and Ca- and Mg-carbonate.

Mixed conifer on limestone (Site L-M)

This watershed in the Sacramento Forest has bedrock composed of highly weathered $CaCO_3$ and about 5% arkosic sandstone with traces of

shell fragments and fossiliferous material.

Mixed conifer on granite (Site G-M)

This site in the Tesuque Watersheds near Santa Fe has bedrock composed of: K-feldspar, plagioclase, quartz, biotite, and other trace minerals.

Spruce-fir on limestone (Site L-Sp)

The Sandia Mountains, east of Albuquerque, New Mexico, are capped by limestone of marine origin. The 0-15 cm depth soil is very well weathered and contains a low percentage of stone material greater than 2 mm diameter. This material was composed of dolomite, quartz, and fine grain sandstones composed of orthoclase and quartz.

Spruce-fir on basalt (Site B-Sp)

This particular site in the Jemez Mountains, located west of Santa Fe, New Mexico, is established on weathered rhyolite and rhyolitic tuft composed of K-feldspar, biotite, and quartz.

Spruce-fir on granite (Site G-Sp)

This site in the Tesuque Watersheds has bedrock composed of: quartz, K-feldspar, plagioclase, biotite, and other trace minerals.

We were not able to locate a spruce-fir forest on sandstone.

RESULTS AND DISCUSSION

The analysis of each size fraction yielded standard errors less than or about equal to 10% of the mean for the majority of the analyses. The results for the stream sediment collections were less variable than those of the soil and bank collections which we feel is the result of the mixing of material from many microsites during stream flow. Gosz et al. (1980) reported actual transported sediment was not chemically different from stream channel sediments for the pine on basalt site and we assume this to be true

of mixed conifer and spruce-fir sites also.

Our hypothesis was that vegetation type (which reflects the biotic and abiotic environment) and parent bedrock and the interaction of these factors in the weathering process would be significant factors in determining the chemical composition of transported sediment. To test this we performed a three level analysis of variance for each constituent with vegetation type, parent bedrock (geology), and site (soil, stream bank, and stream sediment within each watershed) as the three levels. Tables 1 and 2 summarize the results obtained for these analyses. Vegetation type and parent bedrock were found to be significant factors for each component in the fine fractions and for most all in the sand fraction. Also, the vegetation type X parent bedrock interaction factor was significant for all but one component in each size fraction. These results overwhelmingly support the original hypothesis.

The site factor was used in the three level analysis of variance to determine if site within the watershed was a significant factor. The sediment fine fraction was lower in extractable magnesium, extractable potassium, and digestable potassium presumably due to the high water solubility of these componets and replacement by calcium upon exchange sites. Three other components identified site as a significant factor, however, causes of these are more difficult to interpret.

Tables 3 and 4 are the mean values for all chemical analyses presented by vegetation type and parent bedrock. The acid digestion analyses show the pronounced effect bedrock composition has on both the fine and sand fractions. The limestone sites were consistently high in Ca and K while the basalt sites reflect the usually high metal content of these bedrock types

being high in Mg, Fe, Mn, Na, Cu and P. The sandstone sites, although lacking a spruce-fir community, were often the lowest for all components. The differences between bedrock types tended to be greater in the sand fraction than in the fine fraction; the less weathered sand reflected the differences of these bedrock types chemical composition more accurately.

The extractable cations also show the importance of bedrock type with Ca and Mg patterns similar in relationship to the acid digestable analyses, however, extractable K demonstrated little differences between bedrock types.

Total N did show differences among bedrock type with high values in the fine fraction of limestone and granite and the sand fraction of limestone and basalt. However, these values appear to be more closely related to organic content of those size fracitons. Total P did not show a distinct relationship to bedrock.

The effect of vegetation type on the chemical composition of the sediment can be seen with mixed conifer sites consistently high for K, P, Zn, extractable Ca and extractable K in both the fine and sand fractions. Spruce-fir was high in total N, organic matter, and CEC for both size fractions. Pine was high in Na (possibly due to higher evapotranspiration which has a concentrating effect on Na) and consistently low in total N, all exchangeable cations, CEC, and organic matter.

The results suggested that many factors may be correlated with each other. A multiple regression analysis showed CEC and organic matter % to be highly significant factors in explaining N levels in both the fine and sand fractions of channel sediment (Table 5). R^2 values indicate 81 and 91%, respectively, of the total variation was explained by the multiple linear regression model. All extractable cations, total N and P, and

digestable K, Zn, and Cu were all significantly explained in the multiple linear regression by CEC for the sand fraction. These data suggest many nutrient levels could accurately be predicted with the knowledge of a single component or a few components.

One means of graphically presenting the results is the trilinear plot technique (Fig. 2). The trilinear graph plots the relative portions of the cations (expressed in equivalents) for the samples indicated. Plotting the relative proportions in such a manner negates the absolute qualities and represents them in proportion to the total. Thus, samples which have vastly different absolute quantities but similar relative proportions would plot on the same area of the graph.

A few general trends can be detected from the graph. At all sites, the relative proportion of Ca in the extractable cations increased and the relative proportion of Mg decreased in relation to the percentage of Ca and Mg in the acid-digestable fractions. The increase in calcium can be attributed to the higher replacement capabilities of calcium on the exchange sites of soil particles in relation to the other cations (Brady, 1974; Gosz et al., 1980). Although the nutrient concentrations resulting from the acid-digestable and extractable analyses differed, the relationship of each among the different bedrock types remained the same. A bedrock type with a high proportion of Mg, for example, will have a relatively high proportion of Mg absorbed on exchange sites. For a given vegetation (e.g. mixed conifer, Fig. 2) the order of decreasing Mg and increasing Ca was basalt > granite > limestone > sandstone. The extractable analyses showed the same order but were shifted toward the Ca apex. This was true for sediment, bank, and soil samples.

The comparison of vegetation types showed that both digestable and extractable analyses of sediment from basalt plotted closer to the Mg apex than other geologies (Fig. 3). The other extreme is limestone showing the shift toward the Ca apex; the extractable analyses plotting very close to 100% Ca (Fig. 4). On basalt, mixed conifer and spruce-fir plot closer to the Ca apex (both digestable and extractable) which may be due to the higher soil weathering rates of these communities. This conclusion is also substantiated by the visual identification of the minerals from both locations which showed the mixed conifer samples to be less angular and more highly weathered than those under pine.

An example of a graph by which nutrient loss via transported sediment can be estimated knowing bedrock type, vegetation, and sediment output is illustrated in Figs. 5 and 6. The concentration data were used to establish the relationship between the output of an element for various losses of sediment from different vegetation and bedrock types. For example, Campbell et al. (1977) reported the loss of 4330 kg/ha of suspended sediment and bedload material during a 6 month period after a fire in pine (limestone bedrock). The size classes were not reported, however, assuming 50% of that loss was fines and 30% was sands, approximately 115 kg/ha of Ca was lost, appreciably more than the dissolved Ca loss. About 30% (40kg/ha) of this loss was extractable Ca adsorbed to the sediment.

In areas where sediment losses are very low these graphs can be used to indicate the minor importance of suspended sediments in transporting some nutrients. Moore et al. (1978) reported the suspended sediment output was about 4 kg/ha from a spruce-fir watershed on granite. Figure 6 indicates that only about 0.015 kg/ha of Ca would be lost in that sediment (0.01 kg/ha

as extractable) in contrast to 7.5 kg/ha of total Ca output (water soluble plus extractable).

While the results of this study identify the importance of sediment in removing elements from a watershed and the dependence of the magnitude of the loss on bedrock type and vegetation, more work is needed to develop this technique into a useful tool. The bedrock types studied have marked chemical differences; however, we do not know how variable these components are for a given bedrock and vegetation combination (e.g. pine on basalt) in different areas. These results are needed to establish confidence limits for the lines of Figures 5 and 6.

ACKNOWLEDGEMENTS

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Table 1. Three factor analysis of variance results of element concentrations for channel sediment sand size fraction. The main factors are vegetation (V), geology (G), and site (soil, bank, sediment - S). * is $P < .05$, ** is $P < .01$, and *** is $P < .001$.

Element	V	G	S	VG	VS	GS	VGS
Ca		***	*	***	**	***	***
Mg	***	***	**	***	***	**	***
Na	***	***	***	***	***	***	***
K	***			***		*	***
N	***	**		**	*	*	
P	***	***		***	***	***	
Fe	***	***		***	**	**	***
Mn	***	***	*	***	***	***	***
Zn	***	***		***		***	***
Cu	***	***		***		**	***
exCa	*	***		**		*	
exMg		***		*			***
exK	***	**					

Table 2. Three factor analysis of variance results of element concentrations for channel sediment fine size fraction. The main factors are vegetation (V), geology (G), and site (soil, bank, sediment - S). * is $P < .05$, ** is $P < .01$, and *** is $P < .001$.

Element	V	G	S	VG	VS	GS	VGS
Ca	**	***		***		**	**
Mg	***	***		***	**		
Na	**	***	***	***		***	**
K	***	***	*	***		***	***
N	***	***	***		**	***	***
P	***	***		***		**	***
Fe	***	***		***	***	**	*
Mn	***	***		***			
Zn	***	***		***	***	**	**
Cu	*	***	***	*		*	*
exCa	***	***		***	*	***	***
exMg	***	***	***	***	**	***	
exK	***	***	**	***	**	***	***

Table 3. Average digestable and extractable (ex) element concentrations in channel sediment sand size fraction for pine (P), mixed conifer (M), and spruce-fir (S) communities on different bedrock. Values for an element followed by different letters are significantly different ($P < .05$).

Element	Vegetation	Bedrock Limestone	Basalt	Granite	Sandstone
	P	4.16a	0.42b	0.68b	0.17b
Ca%	M	0.95b	0.60b	0.14b	0.79b
	S	0.69b	1.39b	0.07b	
	P	0.20d	3.62a	0.58c	0.07d
Mg%	M	0.13d	1.74b	0.14d	0.21d
	S	0.28cd	1.98b	0.09d	
	P	0.0033ef	0.0580a	0.0062de	0.0021f
Na%	M	0.0078d	0.0132c	0.0033ef	0.0060de
	S	0.0038ef	0.0202b	0.0032ef	
	P	0.025e	0.052de	0.128ab	0.050de
K%	M	0.171a	0.116abc	0.066cde	0.174a
	S	0.095bcd	0.132ab	0.040de	
	P	0.031b	0.026b	0.144b	0.072b
N%	M	0.403a	0.057b	0.090b	0.153b
	S	0.567a	0.437a	0.040b	
	P	0.010ef	0.098b	0.088b	0.012ef
P%	M	0.049cd	0.223a	0.013ef	0.033de
	S	0.059c	0.059c	0.008f	
	P	0.16f	8.76a	3.04d	0.82ef
Fe%	M	0.99ef	7.43b	1.16e	2.99d
	S	0.36ef	4.83c	0.53ef	

Table 3 continued.

Element	Vegetation	Bedrock			
		Limestone	Basalt	Granite	Sandstone
Mn%	P	0.006d	0.357a	0.052cd	0.035cd
	M	0.044cd	0.168b	0.014d	0.041cd
	S	0.048cd	0.100c	0.008d	
Zn ppm	P	7.3e	88.0ab	46.4d	17.3e
	M	47.7d	97.0a	16.3e	78.3bc
	S	45.0d	69.0c	10.0e	
Cu ppm	P	2.3f	53.0a	13.3de	7.7ef
	M	14.7d	45.0b	3.3f	16.0d
	S	19.7d	29.7c	3.0f	
exCa%	P	0.688ab	0.138d	0.334cd	0.145d
	M	0.670ab	0.326cd	0.130d	0.483bc
	S	0.580abc	0.867a	0.040d	
exMg%	P	0.018e	0.044bcd	0.046bc	0.022de
	M	0.026cde	0.081a	0.024cde	0.011e
	S	0.028cde	0.058b	0.007e	
exK%	P	0.006de	0.011cd	0.006de	0.005de
	M	0.023b	0.035a	0.005de	0.012cd
	S	0.011cd	0.019bc	0.002e	
CEC	P	18.5cdef	13.5def	35.9abc	8.6ef
	M	30.0bcd	36.6abc	9.1ef	22.4cde
	S	44.2ab	48.8a	2.8f	
OM%	P	4.1cd	4.5cd	10.8cd	5.9cd
	M	23.4ab	8.7cd	4.6cd	8.2cd
	S	27.7a	16.2bc	1.5d	

Table 4. Average digestable and extractable (ex) element concentrations in channel sediment fine size fraction for pine (P), mixed conifer (M), and spruce-fir (S) communities on different bedrock. Values for an element followed by different letters are significantly different (P <.05).

Element	Vegetation	Bedrock			
		Limestone	Basalt	Granite	Sandstone
	P	2.83a	0.57c	0.99bc	0.49c
Ca%	M	0.83bc	0.74bc	0.86bc	1.50b
	S	0.97bc	1.53b	0.65c	
	P	1.10a	0.82b	0.70bc	0.28de
Mg%	M	0.39de	0.68bc	0.71bc	0.27e
	S	0.54cd	1.13a	0.35de	
	P	0.010bcd	0.045a	0.012bcd	0.008cd
Na%	M	0.010bcd	0.017bc	0.017bc	0.006d
	S	0.007cd	0.019b	0.014bcd	
	P	0.47a	0.19d	0.23d	0.20d
K%	M	0.49a	0.23d	0.37b	0.28c
	S	0.28c	0.20d	0.15e	
	P	0.189d	0.070d	0.184d	0.155d
N%	M	0.320c	0.170d	0.580b	0.513b
	S	0.763a	0.650ab	0.523b	
	P	0.058bc	0.065bc	0.102a	0.024d
P%	M	0.104a	0.103a	0.086ab	0.046cd
	S	0.086ab	0.058bc	0.084ab	
	P	2.14bcd	5.11a	3.34b	1.67d
Fe%	M	2.74bcd	5.65a	2.98bc	2.70bcd
	S	1.92cd	2.74bcd	1.61d	

Table 4 continued.

Element	Vegetation	Bedrock			
		Limestone	Basalt	Granite	Sandstone
	P	0.051b	0.189a	0.064b	0.055b
Mn%	M	0.085b	0.177a	0.073b	0.094b
	S	0.063b	0.048b	0.055b	
	P	72.7cd	70.7cd	67.0cd	61.0cd
Zn ppm	M	104.3a	99.3a	76.7bc	99.0a
	S	90.3ab	62.7cd	59.0d	
	P	27.0c	91.7a	53.3bc	45.0c
Cu ppm	M	30.7c	58.3bc	43.7c	43.3c
	S	30.7c	51.7bc	78.3ab	
	P	1.15a	0.24e	0.31de	0.32de
exCa%	M	0.75bc	0.53cd	0.68bc	1.36a
	S	0.84b	1.18a	0.53cd	
	P	0.041fg	0.098cd	0.059ef	0.061ef
exMg%	M	0.035fg	0.120bc	0.142b	0.025g
	S	0.038fg	0.388a	0.083de	
	P	0.036bcde	0.024ef	0.014f	0.022ef
exK%	M	0.086a	0.050b	0.043bcd	0.032cde
	S	0.049bc	0.027def	0.020ef	
	P	20.3de	44.8abc	13.1e	28.8cd
CEC	M	43.4abc	43.5abc	50.7ab	56.4a
	S	54.9a	57.1a	37.2bc	
	P	10.2e	8.7e	9.4e	14.2cde
O.M.	M	12.8de	16.3bcd	21.8ab	19.8bc
	S	27.0a	20.4b	22.3ab	

Table 5. Multiple linear regression analysis of elements in channel sediment in relation to cation exchange capacity (CEC) and organic matter (O.M.). Asterisks indicate significant increment in sums of squares for the model as each variable is added. The F value and asterisks indicate how well the model as a whole accounts for the variation of the element. The R^2 value indicates the proportion of the total variation explained by the model. N.S. is non-significant, * is $P < .05$, ** is $P < .01$, *** is $P < .001$.

Fines

Element	CEC	O.M.	F Value	R^2
Ca			0.05 N.S.	.00
Mg			1.31 N.S.	.08
Na		*	3.52*	.19
K			0.40 N.S	.03
N	***	***	64.41***	.81
P			0.13 N.S.	.01
Zn	*		2.45 N.S.	.14
Fe		**	6.08**	.29
Cu			0.94 N.S.	.06
Mn		***	8.07**	.35
exCa	**		4.23*	.22
exMg	*		2.30 N.S.	.13
exK			1.98 N.S.	.12

Table 5 continued.

Sand

Element	CEC	O.M.	F Value	R^2
Ca			.98 N.S.	.06
Mg			2.18 N.S.	.13
Na			.42 N.S.	.03
K	***		7.83**	.34
N	***	***	158.1***	.91
P	**		6.22**	.29
Zn	**		5.89**	.28
Fe		*	4.31*	.22
Cu	*		2.77 N.S.	.16
Mn			.49 N.S.	.03
exCa	***		20.06***	.57
exMg	***		10.17***	.40
exK	***		8.39**	.36

FIGURE LEGEND

Figure 1. Location of the study sites in Arizona and New Mexico. See text for descriptions.

Figure 2. Trilinear plot of major cations in channel sediment of mixed conifer watersheds with basalt (B), granite (G), sandstone (S), and limestone (L) bedrock. Acid-digestable levels are indicated by capital letters and extractable levels by lower case letters.

Figure 3. Trilinear plot of major cations in channel sediment from pine (P), mixed conifer (M), and spruce-fir (S) watersheds on basalt bedrock. Acid-digestable levels are indicated by capital letters and extractable levels by lower case letters.

Figure 4. Trilinear plot of major cations in channel sediment from pine (P), mixed conifer (M), and spruce-fir (S) watersheds on limestone bedrock. Acid-digestable levels are indicated by capital letters and extractable levels by lower case letters.

Figure 5. Influence of sediment transport on the transport of acid-digestable and extractable Ca for a pine watershed on different bedrock (L-limestone, G-granite, B-basalt, S-sandstone).

Figure 6. Influence of sediment transport on the transport of acid-digestable and extractable Ca for a spruce-fir watershed on different bedrock (L-limestone, G-granite, B-basalt).

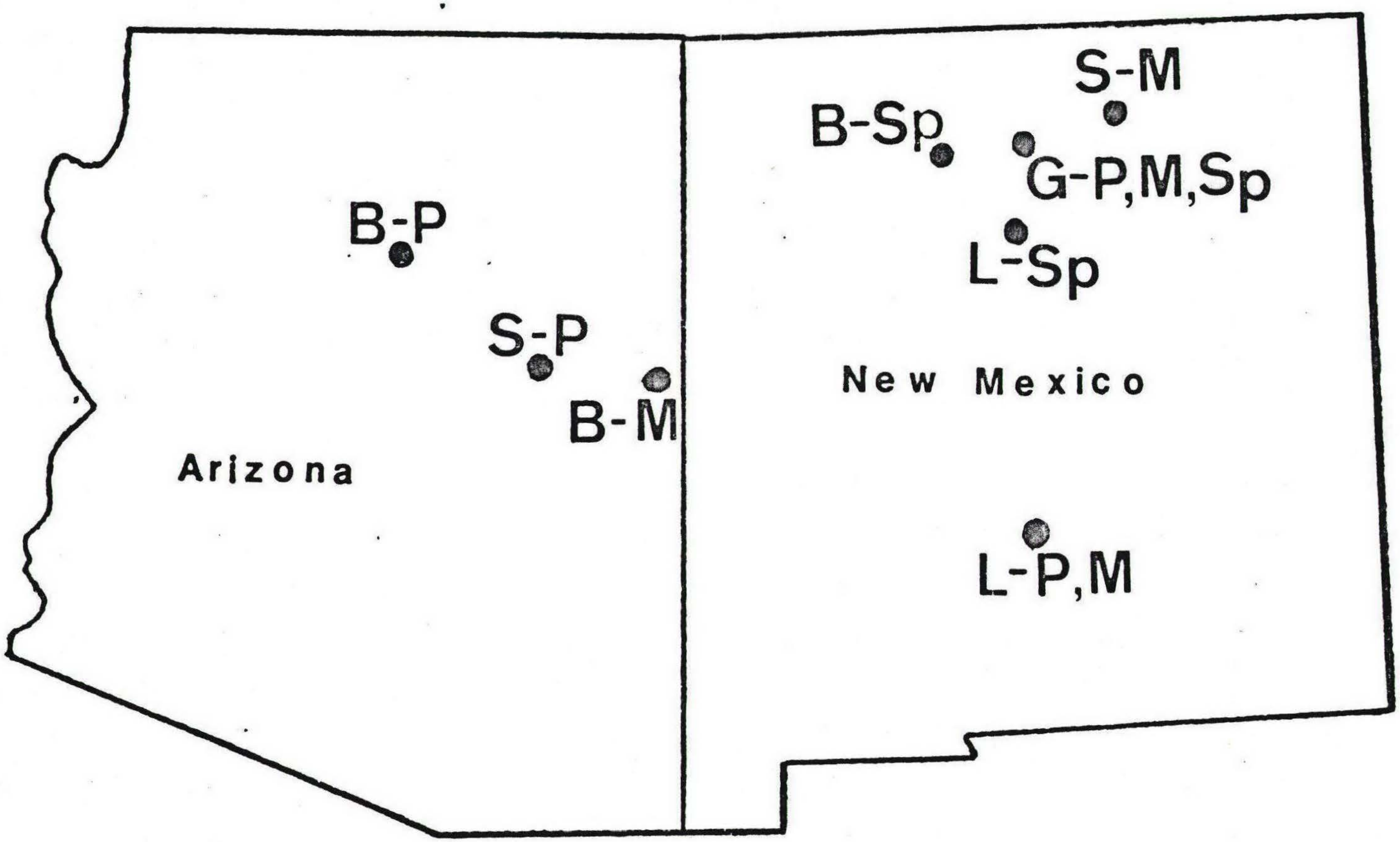


Fig. 1

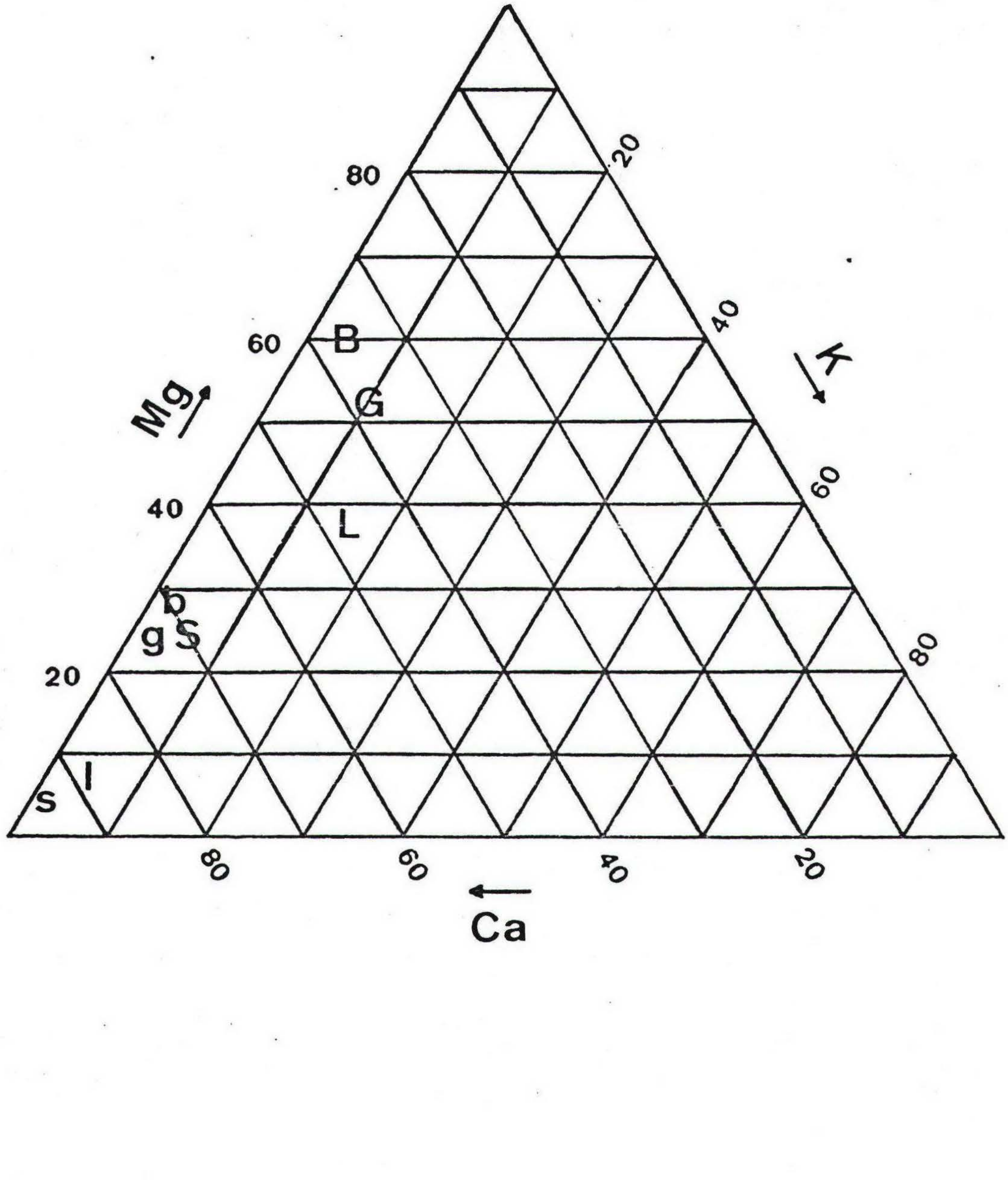


Fig. 2

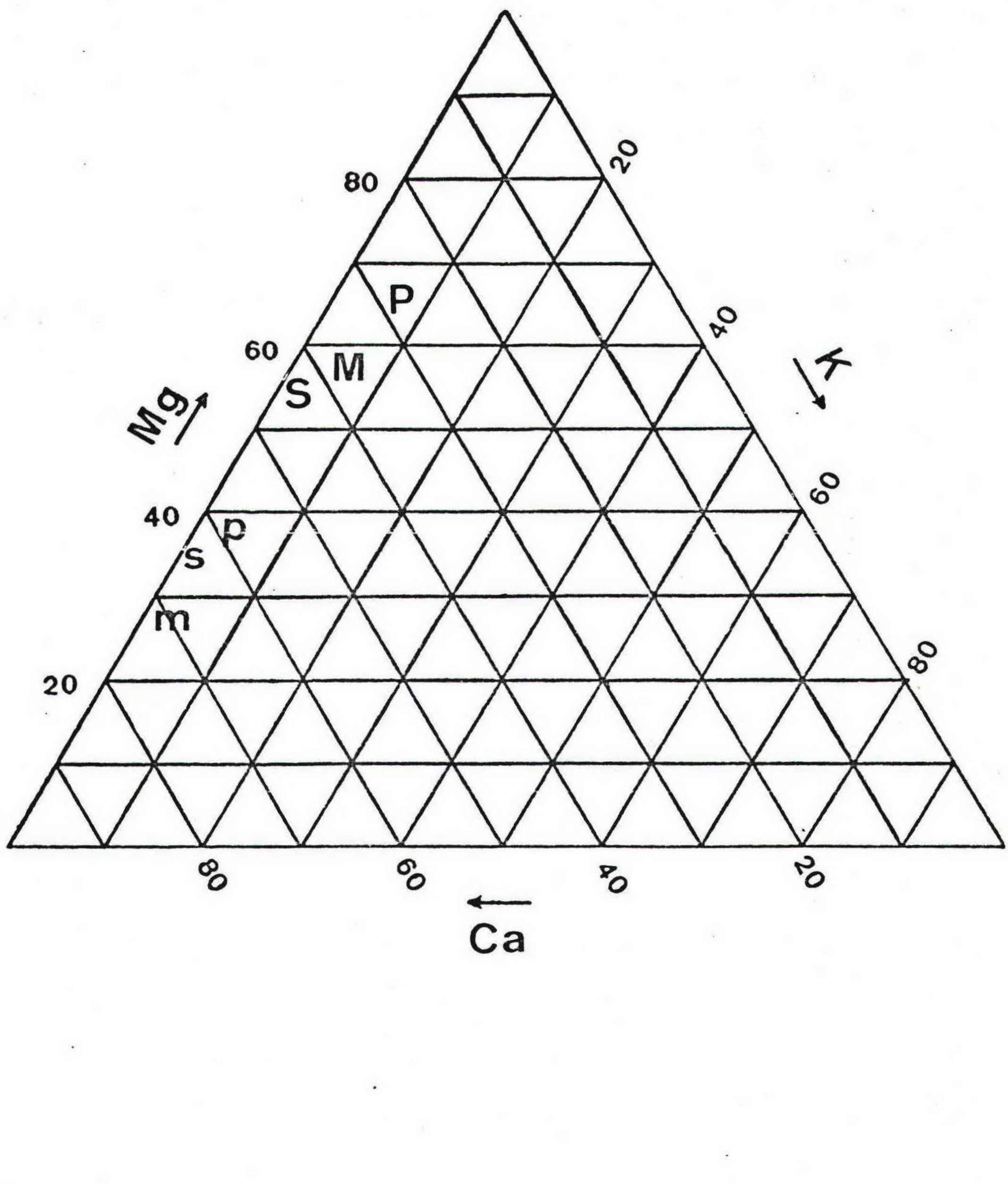


Fig. 3

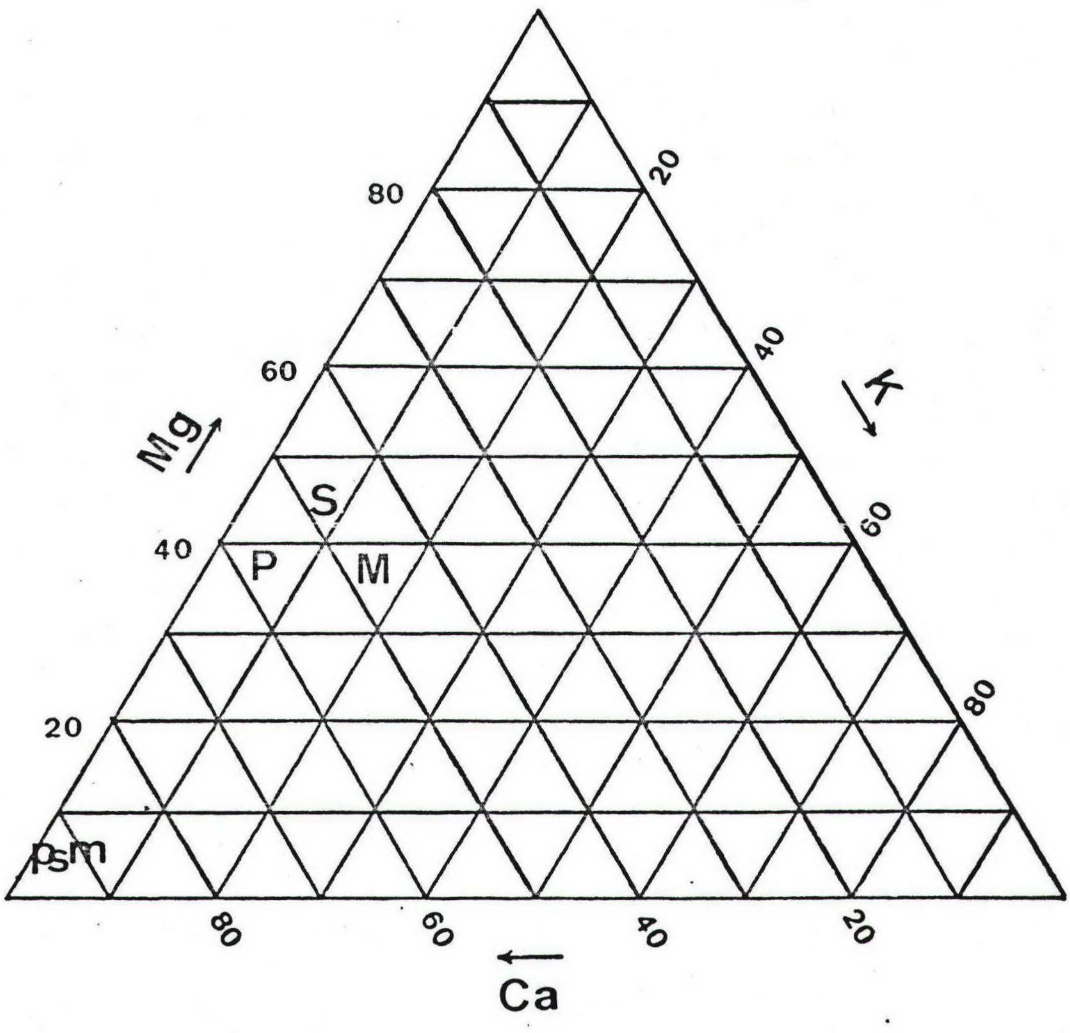
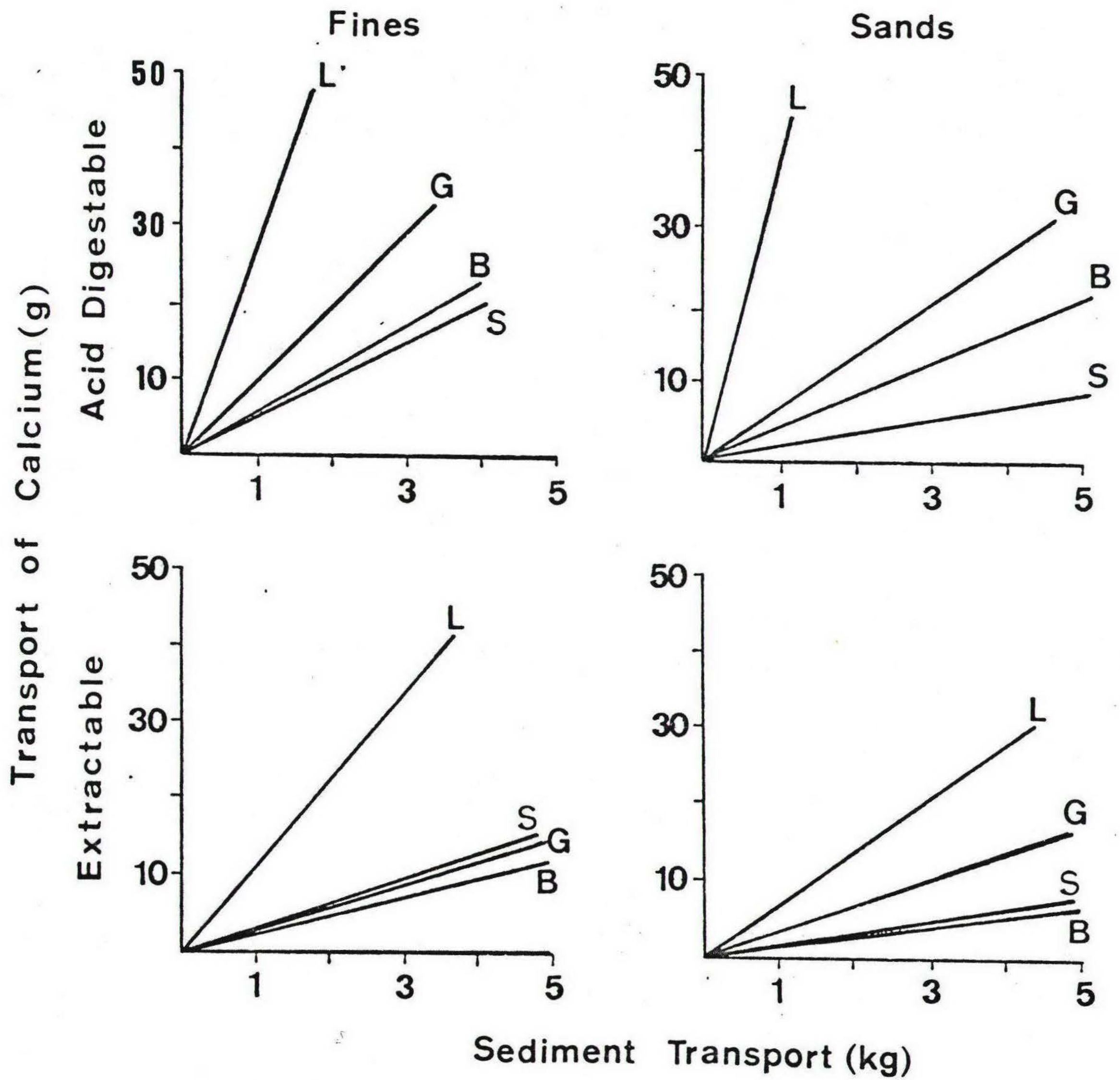
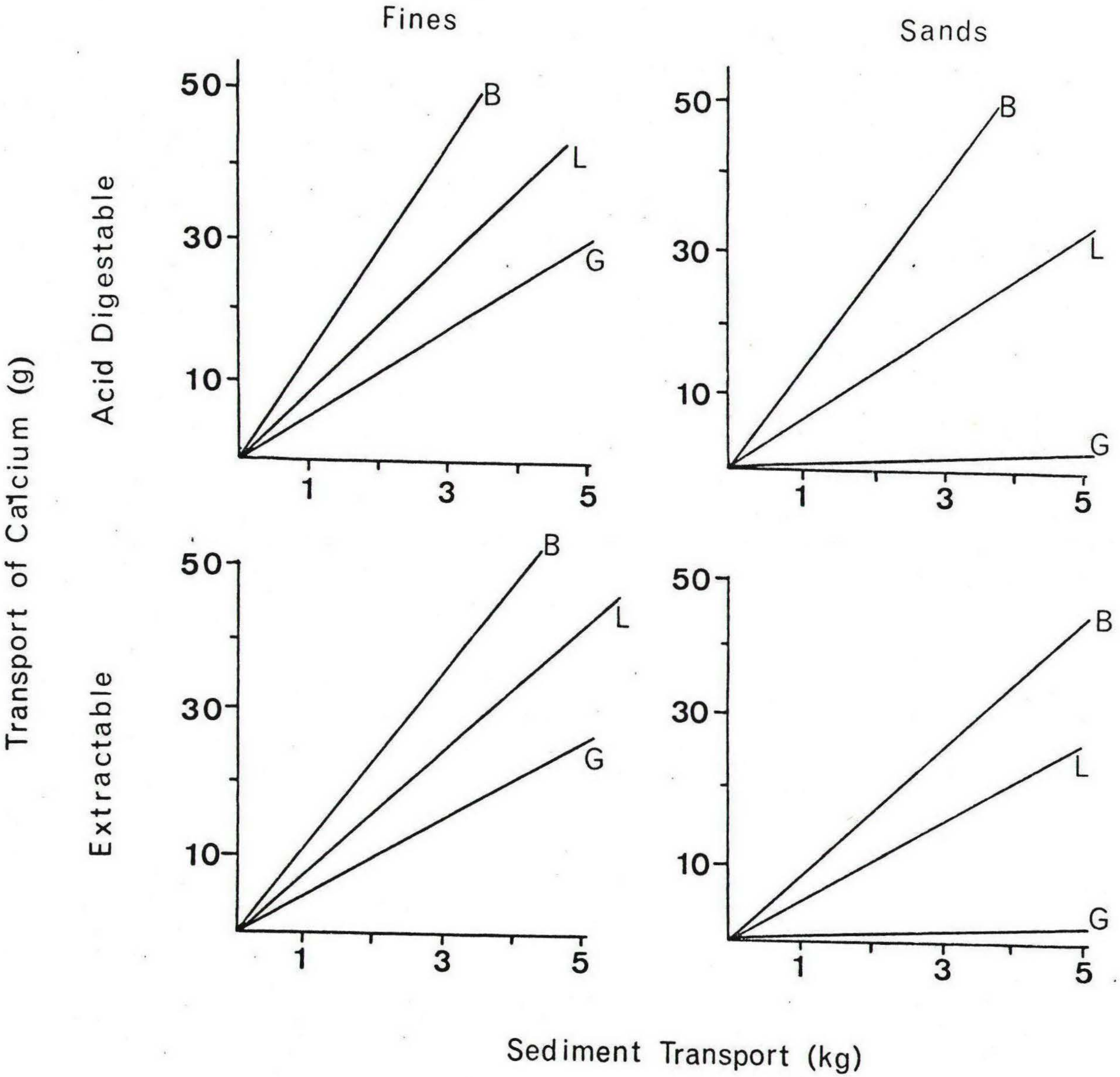


Fig. ~~3~~ 4



Fines
Sands
Transport of Calcium (g)
Acid Digestable
Extractable
50
30
10
1
3
5
L
G
B
S
Sediment Transport (kg)

Fig. 5



Fines
Sands
Transport of Calcium (g)
Acid Digestable
Extractable
50
30
10
1
3
5
B
L
G
Sediment Transport (kg)

Fig. 6

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